Comment on "Decay of the Dst Field of Geomagnetic Disturbance After Substorm Onset and its Implication to Storm-Substorm Relation" by Iyemori and Rao

by

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Over the past few years, there has been a considerable revival in the study of geomagnetic storms stimulated by an increasing knowledge of the energetic particles which comprise the ring current. is only in recent years that the composition of the ring current has been thoroughly explored and the important role of the oxygen component of he near-Earth plasma sheet has become recognized. With increased knowledge of he characteristics of the energetic particle environment, has come a wish to know how the high energy portion of the population develops, which makes the question of energization of ring current particles a matter of prime interest.

Two schools of thought have emerged as his question has been considered. (n one hand, it is thought that ring current particles gain their high energies (tens to hundreds of keV) simply through application of the solar wind electric field to the magnetosphere causing the injection of ring current particles (e.g. Burton et al. 1 75, larel et al., 98 . The argument here is based on the fact ha ring current development can be well predicted using only the interplanetary electric field (IEF) as input. On the other hand, a second school of thought argues that substorm expansive phases involve induction electric fields which cause the energization and injection of plasma sheet particles with he sum of he substorm effects leading to the forma ion of the storm time ring current (e.g. Mauk and Meng, 1986; Chen et al.,1993). It is rather difficult to distinguish between these schools of thought because substorm expansive phases tend to occur during periods of enhanced interplanetary electric field associated with southward interplanetary magnetic field (IMF). In fact, Kamide [1992] has shown that there is ~100% chance of substorm expansive phase activity occurring during the main phase development of a magnetic storm. The primary question is whether or not the expansive phases, which are also caused by energy input from solar wind due to enhanced dawn-to-dusk EF, are simply consequences of the enhanced energy input and play no significant role in the actual acceleration process for ring curren ions

In a recent paper, Iyemori and Rao [1996] (which we refer to as IR in the following comment) claim to have found definitive evidence supporting the view that substorm expansive phases do not play a significant role in symmetric ring curren generation. The purpose of this commentary is to point out that IR have not presented adequate evidence to support the view h: substorm expansive phases are inconsequential in he ring current formation process.

The primary objection centers around Figure 7 of IR reproduced here as our Figure 1. This figure shows data relevant to the substorm main phase (upper panels) and recovery phase (lower panels). We shall confine our comments to the main phase material. The authors compute the asymmetric and symmetric components of the disturbance field, with the symmetric component of the horizontal H-component (SYM-H) being equivalent to the "normal" Dst index although computed from a few more stations han Dst as it is presently provided to the research community. A superposed epoch technique is used with the time $t = 0$ being the onse in e of substorm expansive phases occurring during the growth of the storm main phase ring current. The authors argue that "It is clear that the Dst (SYM-H) field does not show any development after the onset. The slope of the SYM-H indicates sudden change to positive direction rather than the expected negative." The authors guide the readers eye by showing the expected (linear) trend in SYM-H which they wish the reader to believe would be observed if, indeed the substorm expansive phase were to have an impact on he growth of the ring current.

We would argue on the basis of this figure that Dst does grow, not only in the hour after expansive phase onset, but even in the succeeding hour. The expectation that the initial ring curren formation would be somewhat asymmetric, with a tendency to become more symmetric as ions of different energy drift longitudinally at different speeds is borne out by the data which show the asymmetry declining in the second hour after expansive phase onset while SYM-H becomes somewhat larger. We believe, in fact, that the data presented in the top panels of Figure 7 might even suggest that the occurrence of a substorm expansive phase is associated with symmetric ring current growth as quantified by Dst (or SYM-H in this case). While it may be claimed that the rate of growth of the ring current seems to decrease in association with the expansive phase onset compared to prior to the onset, this argument fails for the following reason. A large substorm expansive phase onset usually involves the growth of the wedge field-aligned current and a decrease in crosstail current near the Earth. At least in the first hour or two after onset, both these expansive phase effects would be expected to produce positive H-component disturbances which will affect SYM-H to the extent of giving it a positive increase. '1'1)(! very fact that SYM-H decreased further in the hour after the expansive phase (111 set indicates that the ring current grew significantly immediately after onset, part of the magnetic effect being cancelled by the wedge and crosstail current magnetic field changes.

We would also like to make some constructive comments regarding the analysis of the data on which one tries to base conclusions dealing with storm-substorm relationships. The main point to stress is that we would probably now understand storm-substorm relationships if only there were adequate data available to, with minimum ambiguity, globally describe expansive phase activity and its precursors. In any event, researchers 1)111S[bring to bear as much relevant data as they can muster or run the risk of reaching inappropriate conclusions based on a limited amount (I I' information.

The problems that can arise in working wit}) a limited data set are exemplified in the treatment of the event 01" September 22, 1987 shown in Figure 3 of IR reproduced here as our Figure 2. They present this event in support of the contention of Russell et al. [1974] that Dst relates more closely to the southward IMF than it does to substorm activity. They use their ASY index as an indicator of substorm expansive phase activity, relating little or no change in ASY to an absence of expansive phase activity. Thus, the authors use the lack of response OI'A, S% during the interval 16-17 UT (III September 22 to argue that SYM-H (i.e. Dst) increases while no substorm expansive phase activity is in progress. However, the limited number of stations used to compute ASY makes it quite possible that expansive phase activity was in progress but simply did not produce large perturbations at the available stations used to compute the index. For example, in the very same diagram, significant expansive phase activity must have been taking place in the interval 08-09 UT on September 22 (as evidenced from the sudden large increase in AL in that hourly interval) and yet ASY seems to show a response no larger than during the interval 16-17 UT (when it was claimed that no expansive phase activity occurred). This points out the danger of using indices to evaluate individual events. While indices such as ASY can be useful in statistical studies of geomagnetic activity, the relatively small number of stations whose data are used to compute the index makes it all too possible for some events to be overlooked because their maximum perturbations occur where no station is available to monitor them.

A further point we note with this event is that changes in SYM-H can also be produced by changes in solar wind pressure. IR chose not to explore the solar wind velocity and number density during the interval (16-17 UT) deciding instead to show only IMF data and relating the negative increase in SYM-H from 16 UT only to the AE, ASY and IMF variations. In reality, there was a significant increase in solar wind pressure starting ~1530 UT stemming primarily from an increase in solar wind number density by a factor of ~4. IR measures the negative shift of SYM-H from a baseline taken after the pressure increase. From ~1640-1715 UT the solar wind pressure declines significantly (as measured by IMP 8 ~30 Re in front of the earth) so a good portion (-40 nT) of the negative shift of SYM-H is due to a brief return of the magnetosphere to its pre-event configuration. (This estimate stems from use of the solar wind correction algorithm found in Gonzalez et al. [1989] which follows the formalism of Burton et al. [1975].) The onset of the substorm expansive phase ~1725 UT occurs almost at the same time as the solar wind pressure increases again due to a number density enhancement. The fact that SYM-H does not respond at substorm onset suggests that the positive increase expected in SYM-H due to the solar wind pressure enhancement is balanced by a negative increase due to increased ring current. [Also, associated with a substorm expansive phase, one would expect a decrease in crosstail current close to the earth which would also tend to make SYM-H increase positively demanding an increased ring current to cancel that effect.] The purpose of this detailed discussion is to emphasize again how important it is to use all available data in approaching the question of how substorms and the storm time ring current are related to one another.

In summary the conclusions of Iyemori and Rao [1996] that ring current growth is unrelated to substorm activity are not supported by the data they present. They have, of course, addressed a very important questions which has occupied the attention of many researchers (cf. Gonzalez et al., 1994) and which was a major topic of discussion at the recent Chapman Conference on Magnetic Storms held in February 1996 in

Pasadena, California. We cannot, ourselves, a his time answer he question regarding what, if any relationship there is between storms and substorms. t may well be that the premise explored by the authors is not incorrect but we argue that hey have not proven it. Nonetheless, we feel that the question of whether or not substorms play an important role in ring current formation is very importan and must be explored thoroughly in the future.

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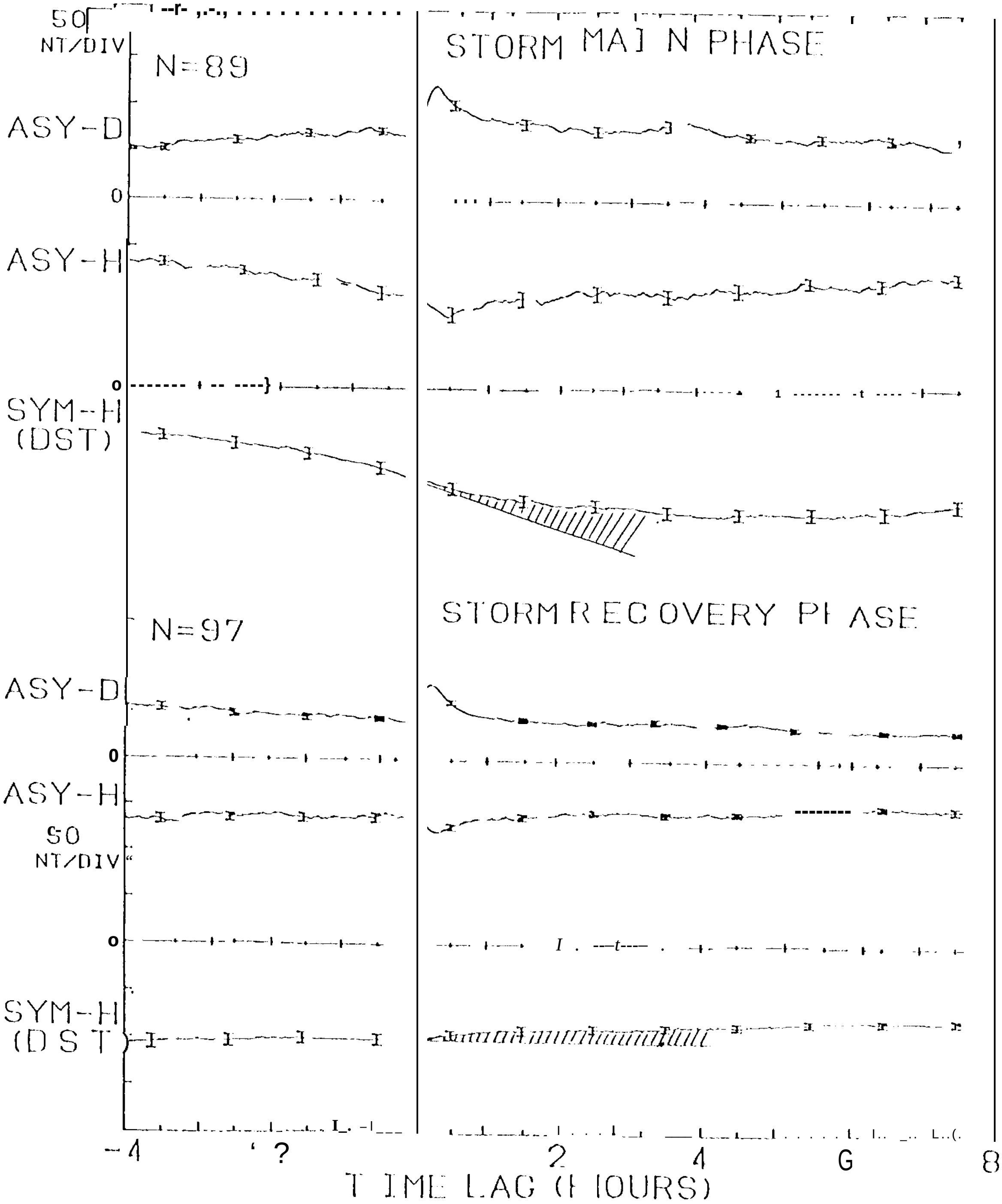
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(DST)
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2
4
6
8
TIME LAG (HOURS)

FIGURE 1

I.A. Figure 3

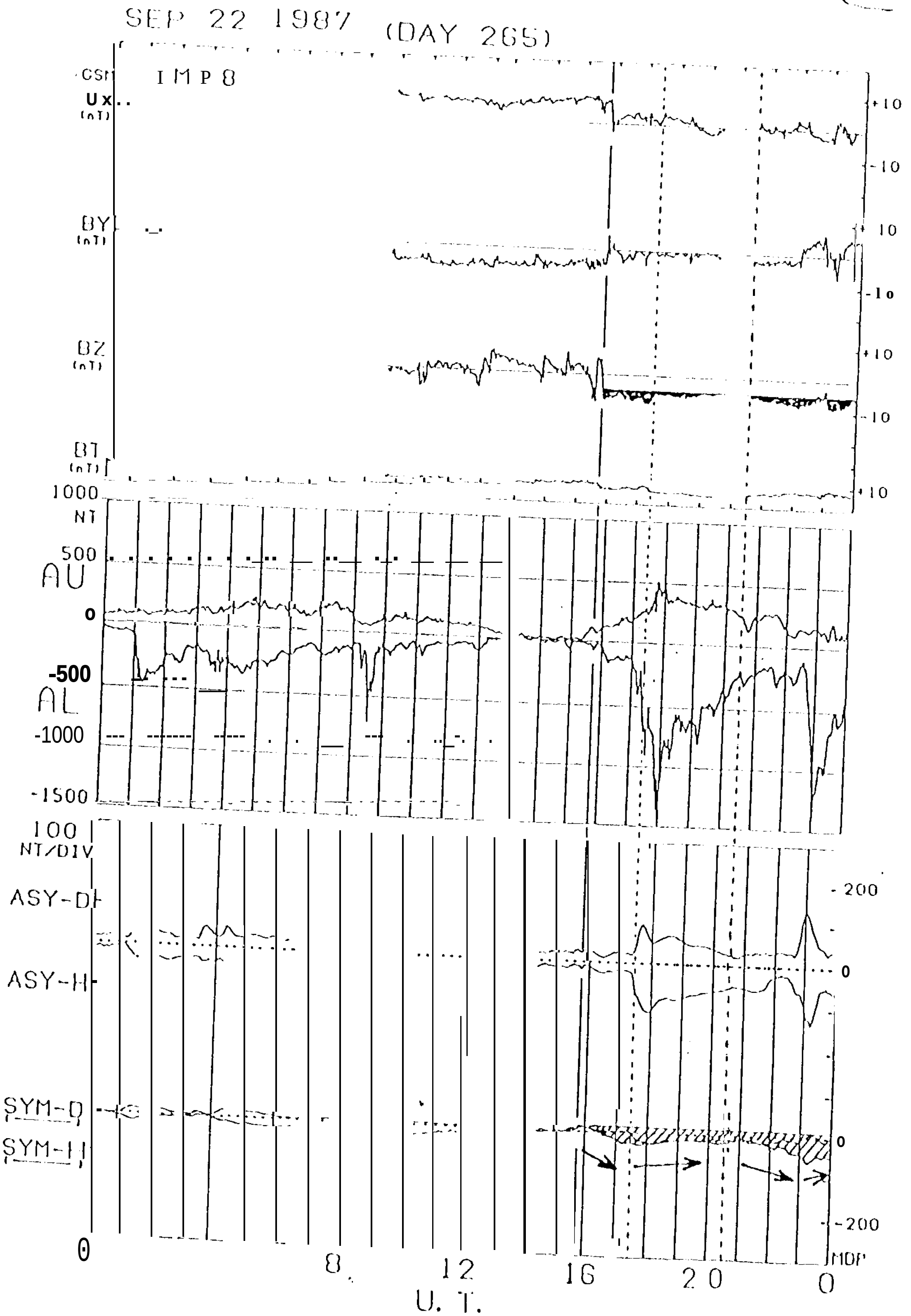

FIGURE 2